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(54) Title: PORTABLE ELECTROSPINNING DEVICE

(57) Abstract: An electrospinning device for generating a coat from a liquefied polymer, the device comprising: (a) a dispenser for dispensing the liquefied polymer; (b) a cavity having a longitudinal axis, comprising a first system of electrodes; the dispenser and the first system of electrodes being constructed and design such that the liquefied polymer is dispensed from the dispenser and forms a plurality of polymer fibers moving along the longitudinal axis; and (c) a mechanism for relocating the polymer fibers out of the cavity, in a direction of an object, so as to generate a coat on the object.

PORTABLE ELECTROSPINNING DEVICE

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to an electrospinning device and, more particularly, to a portable electrospinning device useful in providing a coat onto a verity of objects, such as wounds and the like.

Skin dressing materials used for covering skin defects are required, in general, to have skin compatibility, low or no skin irritation characteristics and sufficiently flexibility, so as to expand as the skin there underneath moves. In addition, it is desired that such skin dressing materials will serve as a barrier against infection agents, such as bacteria, so as to prevent infections.

When a skin defect is characterized by a large area of skin loss, such as in the case of a burn, the defect region is first treated by being covered with a conventional wound dressing material, as a first aid, and then via grafting of skin from other parts of the body.

Known in the art are wound dressings consisting of a thin flexible material, having an adhesive on one side, which are applied to an open wound of a patient following medical treatment of the wound. The flexible nature of the material permits the dressing to conform to virtually any contour of the patient at the location where the dressing is applied.

Typical wound dressings, however, are often applied to the patient during or after stretching of the dressing. Such stretching is known to cause discomfort to the patient and irritation to the area surrounding the wound. Moreover, on weak or damaged skin, as in the elderly, the stretching forces can cause serious skin damage. Furthermore, the flexibility of conventional skin dressing materials comes into question because these materials, once stretched, do not flexibly deform enough following the movement of the skin, which sometimes causes discomfort and/or pain.

The process of application of the wound dressing onto a wounded site often requires contact between fingers and the surface of the material during application, which contact may contaminate the surface adjacent to the wound beneath the dressing. Hence, maintaining the sterility of the dressing during the application process is an important consideration when designing a wound dressing.

It is recognized that the healing of a wound occurs as the epithelium migrates by growth generally from the periphery inward. Therefore, care is taken not to damage unnecessarily or to irritate this new area of growth or existing compromised tissue.

Many local treatments of cuts, wounds, burns and the like require some kind of pharmaceutical agent to be applied on the damaged site, prior to the application of a wound dressing. The advantages gained by local therapy include high concentrations of the drug at the actual site of injury. However, since in these treatments the medication is dispensed over an open wound, the wound dressing need to be stripped off before treating the wound.

Frequently, with prior art dressings, problems can occur during dressing changes, *e.g.* when the dressing adheres to the epithelium. In these instances, there is a risk that removal of the dressing will damage the sensitive tissue and new growth, thereby causing a regression in the progress of wound healing.

Considering the various types of wounds, the numerous dressings that are presently available, and the various stages of healing, there remains a need for a substantially sterile dressing that minimizes damages to the injured site, both during the application and during the removal of the dressings.

The present invention provides solutions to the problems associated with prior art wound dressing techniques.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided an electrospinning device for generating a coat from a liquefied polymer, the device comprising: (a) a dispenser for dispensing the liquefied polymer; (b) a cavity having a longitudinal axis, comprising a first system of electrodes; the dispenser and the first system of electrodes being constructed and design such that the liquefied polymer is dispensed from the dispenser and forms a plurality of polymer fibers moving along the longitudinal axis; and (c) a mechanism for relocating the polymer fibers out of the cavity, in a direction of an object, so as to generate a coat on the object.

According to further features in preferred embodiments of the invention described below, the mechanism comprises at least one blower, positioned adjacent to the dispenser, and generating an airflow substantially directed along the longitudinal axis.

According to still further features in the described preferred embodiments the electrospinning device further comprising a first reservoir for holding the liquefied polymer.

According to still further features in the described preferred embodiments the electrospinning device further comprising a second reservoir for holding a pharmaceutical agent to be mixed with the liquefied polymer.

According to another aspect of the present invention there is provided a method of generating a coat from a liquefied polymer, the method comprising dispensing the liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of polymer fibers moving along the longitudinal axis, and relocating the polymer fibers out of the cavity, in a direction of an object so as to generate a coat onto the object.

According to further features in preferred embodiments of the invention described below, the method further comprising incorporating at

least one drug within the liquefied polymer, for delivery of the at least one drug into a vasculature of the organism, during or after generating the coat.

According to yet another aspect of the present invention there is provided a nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing having at least one characteristic selected from the group consisting of: (a) having a predetermined porosity; (b) flexible in accordance with a motion of the individual; (c) removable when placed under a sufficient amount of liquid; and (d) having at least one drug incorporated therein, for delivery of the at least one drug into the body vasculature during or after application of the wound dressing.

According to still another aspect of the present invention there is provided a nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing having at least two characteristics selected from the group consisting of: (a) having a predetermined porosity; (b) flexible in accordance with a motion of the individual; (c) removable when placed under a sufficient amount of liquid; and (d) having at least one drug incorporated therein, for delivery of the at least one drug into the body vasculature during or after application of the wound dressing.

According to an additional aspect of the present invention there is provided a nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing having at least three characteristics selected from the group consisting of: (a) having a predetermined porosity; (b) flexible in accordance with a motion of the individual; (c) removable when placed under a sufficient amount of liquid; and (d) having at least one drug incorporated therein, for delivery of the at least one drug into the body vasculature during or after application of the wound dressing.

According to yet an additional aspect of the present invention there is provided a nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing: (a) having a predetermined porosity; (b) flexible in accordance with a motion of the individual; (c) removable when placed under a sufficient amount of liquid; and (d) having at least one drug incorporated therein, for delivery of the at least one drug into the body vasculature during or after application of the wound dressing.

According to further features in preferred embodiments of the invention described below, the nonwoven sterile wound dressing is an artificial skin.

According to still further features in the described preferred embodiments the polymer fibers are biocompatible.

According to still further features in the described preferred embodiments the polymer fibers are selected from the group consisting of biodegradable polymer fibers and biostable polymer fibers.

According to still an additional aspect of the present invention there is provided a method of connecting two vessels having open ends, the method comprising, attaching the two open ends of the two vessels and, via electrospinning, providing a coat onto at least a portion of the two vessels so as to adhere the two open ends.

According to further features in preferred embodiments of the invention described below, providing a coat comprises dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of polymer fibers moving along the longitudinal axis, and relocating the polymer fibers out of the cavity, in a direction of the at least a portion of the two vessels.

According to still further features in the described preferred embodiments the method further comprising incorporating at least one drug

within the liquefied polymer, for delivery of the at least one drug into at least one vessel during or after providing the coat.

According to a further aspect of the present invention there is provided a method of recording a fingerprint of an individual having a finger, the method comprising: via electrospinning, coating the finger by a nonwoven material; and removing the nonwoven material from the finger so as to produce data information representative of the fingerprint of the finger.

According to further features in preferred embodiments of the invention described below, coating comprises dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of the polymer fibers moving along the longitudinal axis, and relocating the polymer fibers out of the cavity, in a direction of the finger so as to generate a coat onto the finger.

According to yet a further aspect of the present invention there is provided a method of adhering two objects having contact surfaces, the method comprising: via electrospinning, coating at least one contact surface by a nonwoven material; and attaching the contact surfaces together hence adhering the two objects.

According to further features in preferred embodiments of the invention described below, the nonwoven material is made from polymer fibers.

According to still further features in the described preferred embodiments coating comprises dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of the polymer fibers moving along the longitudinal axis, and relocating the polymer fibers out of the cavity, in a direction of the at least one contact surface.

According to yet a further aspect of the present invention there is provided a method of wound dressing by electrospinning, the method

comprising dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of polymer fibers moving along the longitudinal axis, and relocating the polymer fibers out of the cavity, in a direction of an object so as to generate a wound dressing onto the object.

According to further features in preferred embodiments of the invention described below, the relocating is done by airflow.

According to still further features in the described preferred embodiments the object is a portion of a body of an organism.

According to still further features in the described preferred embodiments the object is a skin of an organism.

According to still further features in the described preferred embodiments the object is a wounded skin of an organism.

According to still further features in the described preferred embodiments the portion is selected from the group consisting of an internal portion and an external portion of the organism.

According to still further features in the described preferred embodiments the object is a blood vessel.

According to still further features in the described preferred embodiments the object is selected from the group consisting of an artery and a vein.

According to still further features in the described preferred embodiments the object is a rotating mandrel.

According to still further features in the described preferred embodiments the dispensing is done by a dispenser.

According to still further features in the described preferred embodiments the dispenser comprises a mechanism for forming a jet of the liquefied polymer.

According to still further features in the described preferred embodiments the mechanism for forming a jet of the liquefied polymer includes a dispensing electrode.

According to still further features in the described preferred embodiments the first electric field is generated by the dispensing electrode and by a first system of electrodes.

According to still further features in the described preferred embodiments the first system of electrodes comprises a circular electrode being at a first potential relative to the dispenser, and spaced apart from the dispenser, along the longitudinal axis.

According to still further features in the described preferred embodiments the method further comprising intertwining at least a portion of the plurality of polymer fibers, so as to provide at least one polymer fiber bundle moving along the longitudinal axis.

According to still further features in the described preferred embodiments the intertwining is done by a second system of electrodes, being laterally displaced from the dispenser, being at a second potential relative to the dispenser and capable of providing a second electric field having at least one rotating component about the longitudinal axis.

According to still further features in the described preferred embodiments the second system of electrodes includes at least one rotating electrode, operable to rotate about the longitudinal axis.

According to still further features in the described preferred embodiments the cavity is designed such that the airflow velocity increases as a function of a distance from the dispenser along the longitudinal axis.

According to still further features in the described preferred embodiments the cavity is characterized by a gradually decreases cross-sectional area along a direction of motion of the polymer fibers.

According to still further features in the described preferred embodiments the cavity comprises a perforated plate positioned at a first terminal of the cavity.

According to still further features in the described preferred embodiments the cavity is opened at a second terminal of the cavity.

According to still further features in the described preferred embodiments the method further comprising incorporating at least one drug within the liquefied polymer, for delivery of the at least one drug into the vessel during or after generating the coat.

According to still further features in the described preferred embodiments the liquefied polymer is biocompatible.

According to still further features in the described preferred embodiments the liquefied polymer is selected from the group consisting of a biodegradable liquefied polymer and a biostable liquefied polymer.

The present invention successfully addresses the shortcomings of the presently known configurations by providing a method and apparatus for providing a nonwoven coat far exceeding prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those

skilled in the art how the several forms of the invention may be embodied in practice.

In the drawings:

FIG. 1 is a schematic illustration of a prior art electrospinning apparatus;

FIG. 2 is a schematic illustration of an electrospinning device for generating a coat from a liquefied polymer, according to the present invention;

FIG. 3 is a is a schematic illustration of the electrospinning device further comprising a mechanism for intertwining at least a portion of the polymer fibers, according to the present invention;

FIG. 4 is a schematic illustration of the intertwining mechanism in the form of a plurality of stationary electrodes, according to the present invention; and

FIG. 5 is a schematic illustration of the intertwining mechanism in the form of at least one rotating electrodes, according to the present invention;

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of an electrospinning device which can be used for generating a coat from a liquefied polymer. Specifically, the present invention can be used to provide first aid for wounds, burns, cuts and the like, and to fabricate artificial skin. Additionally, the present invention can be used to record fingerprints, to connect any two objects such as blood vessels, and to provide a coat to various objects having composite shapes.

For purposes of better understanding the present invention, as illustrated in Figures 2-5 of the drawings, reference is first made to the construction and operation of a conventional (i.e., prior art) electrospinning apparatus as illustrated in Figure 1.

Figure 1 illustrates an apparatus for manufacturing a nonwoven material using a conventional electrospinning apparatus, which is referred to herein as apparatus **10**.

Apparatus **10** includes a dispenser **12** which can be, for example, a bath provided with one or more capillary apertures **14**. Dispenser **12** serves for storing the polymer to be spun in a liquid form, *i.e.*, dissolved or melted. Dispenser **12** is positioned at a predetermined distance from a precipitation electrode **16**. Precipitation electrode **16** serves for forming a structure thereupon. Precipitation electrode **16** is typically manufactured in accordance with the geometrical properties of the final product which is to be fabricated.

Dispenser **12** is typically grounded, while precipitation electrode **16** is connected to a source of high voltage, preferably of negative polarity, thus forming an electric field between dispenser **12** and precipitation electrode **16**. Alternatively, as shown in Figure 1, precipitation electrode **16** can be grounded while dispenser **12** is connected to a source **18** of high voltage with positive polarity.

To generate a nonwoven material, a liquefied polymer (*e.g.*, melted polymer or dissolved polymer) is extruded, for example under the action of hydrostatic pressure, or using a pump (not shown in Figure 1), through capillary apertures **14** of dispenser **12**. As soon as meniscus of the extruded liquefied polymer forms, a process of solvent evaporation or cooling starts, which is accompanied by the creation of capsules with a semi-rigid envelope or crust. An electric field, occasionally accompanied by a unipolar corona discharge in the area of dispenser **12**, is generated by the potential difference between dispenser **12** and precipitation electrode **16**. Because the liquefied polymer possesses a certain degree of electrical conductivity, the above-described capsules become charged. Electric forces of repulsion within the capsules lead to a drastic increase in hydrostatic

pressure. The semi-rigid envelopes are stretched, and a number of point micro-ruptures are formed on the surface of each envelope leading to spraying of ultra-thin jets of liquefied polymer from dispenser **12**.

Under the effect of a Coulomb force, the jets depart from dispenser **12** and travel towards the opposite polarity electrode, *i.e.*, precipitation electrode **16**. Moving with high velocity in the inter-electrode space, the jet cools or solvent therein evaporates, thus forming fibers which are collected on the surface of precipitation electrode **16**.

When using precipitation electrodes characterized by sharp edges and/or variously shaped and sized recesses, the electric field magnitude in the vicinity of precipitation electrode **16** may exceed the air electric strength (about 30 kV/cm), and a corona discharge may develop in the area of precipitation electrode **16**. The effect of corona discharge decreases the coating efficiency of the process as described hereinbelow, and may even resultant in a total inability of fibers to be collected upon precipitation electrode **16**.

Corona discharge initiation is accompanied by the generation of a considerable amount of air ions having opposite charge sign with respect to the charged fibers. Since an electric force is directed with respect to the polarity of charges on which it acts, theses ions start to move at the opposite direction to fibers motion *i.e.*, from precipitation electrode **16** towards dispenser **12**. Consequently, a portion of these ions generate a volume charge (ion cloud), non-uniformly distributed in the inter-electrode space, thereby causing electric field lines to partially close on the volume charge rather than on precipitation electrode **16**. Moreover, the existence of an opposite volume charge in the inter-electrode space, decreases the electric force on the fibers, thus resulting in a large amount of fibers accumulating in the inter-electrode space and gradually settling under gravity force. It

will be appreciated that such an effect leads to a low-efficiency process of fiber coating.

Using a large radius cylinder or a substantially flat plane as a precipitation electrode may diminish the effect described above. However, this effect is severe and limiting when complicated precipitation electrodes are employed for fabricating intricate-profile structures. Moreover, apparatus **10** is typically designed for manufacturing a nonwoven material having a predetermined structure, or for coating an object which is mounted on a rotating mandrel.

It is recognized that such requirements limit the number of possible applications for which apparatus **10** can be employed. For example, apparatus **10** cannot be used for coating objects which are too large or too complicated for being mounted on a rotating mandrel, or for coating a portion of a blood vessel during surgery.

In a conventional electrospinning process as described hereinabove the precipitation is done within a substantially high electric field, thus the process may only be employed for coating objects which may be positioned under high voltage. Furthermore, the presence of electric field near precipitation electrode **16** prevents fibers from penetrating into narrow openings, inclined shapes, etc. whenever such structures exist in precipitation electrode **16**.

While reducing the present invention to practice, it was uncovered that the above limitations can be overcome by a providing a substantial drop of the electric field strength in the vicinity of the object to be coated by the fibers.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is

capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

Referring now again to the drawings, Figure 2 illustrates an electrospinning device, generally referred to herein as device **20**, for generating a coat from a liquefied polymer according to the teachings of the present invention. Device **20** includes a dispenser **22** for dispensing the liquefied polymer, and a cavity **24** having a longitudinal axis **26**, and comprising a first system of electrodes **28**. System of electrodes **28** may be, for example, a circular electrode.

According to a preferred embodiment of the present invention dispenser **22** and first system of electrodes **28** are constructed and design such that the liquefied polymer is dispensed from dispenser **22** and forms a plurality of polymer fibers moving along longitudinal axis **26**, as detailed hereinabove with respect to apparatus **10**. Hence dispenser **22** and system of electrodes **28** are kept under a potential difference generate an electric field therebetween.

Device **20** further includes a mechanism **30** for relocating the polymer fibers out of cavity **24**, in a direction of an object **32**, so as to generate a coat on object **32**. Mechanism **30** may include, for example, at least one blower, positioned adjacent to dispenser **22**. The blower is configured to generate an airflow substantially directed along longitudinal axis **26**, to maintain the velocity of the polymer fiber while passing near system **28**.

Cavity **24** preferably comprises a perforated plate **25** positioned at a first terminal **27** of cavity **24**, so as to allow sufficient airflow from mechanism **30** which is preferably located outside cavity **24**, behind

dispenser **22**. At a second terminal **29**, near system of electrodes **28**, cavity **24** is opened.

According to a preferred embodiment of the present invention cavity **24** is designed such that the airflow velocity increases as a function of a distance from dispenser **22** along longitudinal axis **26**. A typical example for such design is a gradually decreased cross-sectional area of cavity **24** as a function of a distance from dispenser **22** along longitudinal axis **26**.

In order to provide the desired electric field, dispenser **22** and system of electrodes **28** are kept under a potential difference. In accordance with a preferred electrostatic configuration of the invention, dispenser **22** is kept under a positive polarity potential and both system of electrodes **28** and object **32** are grounded, *i.e.*, being at earth-zero potential. Such electrostatic configuration is intended to substantially diminish any remnant component of electric field between apparatus **20** and object **32**.

According to a preferred embodiment of the present invention, dispenser **22** comprises a mechanism for forming a jet of the liquefied polymer, such as, but not limited to, a dispensing electrode, manufactured as a needle. Additionally, dispenser **22** may include a first reservoir **36** for holding the liquefied polymer. In operation mode of device **20**, a jet of the liquefied polymer is dispensed by dispenser **22**, and then, subjected to the electric field, moves through cavity **24**, substantially along longitudinal axis **26**. As described hereinabove, the jet cools or solvent therein evaporates, thus forming the polymer fibers. Beside the electrical forces present between the charged fibers and the electric field, additional mechanical forces, generated by mechanism **30**, act on the polymer fibers concertedly with the electric forces.

Unlike a conventional electrospinning apparatus (*e.g.*, apparatus **10**), high air flow rate near system of electrodes **28**, prevent fiber sedimentation on system of electrodes **28**, although high attractive electric forces may be

present between system of electrodes **28** and the polymer fibers. This phenomenon may be explained both by the mechanical forces directing the fibers outward of cavity **24** and by a presence of an air interlayer which serve for "lubricating" system of electrodes **28**. For example, in a preferred embodiment in which system of electrodes **28** is a circular electrode (see Figure 2), the airflow carries the polymer fibers through the circular electrode. In accordance with a preferred embodiment of the present invention, the velocity of the airflow generated by mechanism **30** increases due to the special geometry of cavity **24**. Thus, the relocating effect of mechanism **30** is optimized by cavity **24**.

Hence, device **20**, which may be manufactured as a compact portable device, essentially serves as an electrostatic sprayer. Since outside the device the electric field is absent, orientation of fiber movement is maintained only by the mechanical forces due to airflow, which are sufficient for fiber relocation. Since air flow is known to have a decaying property, the velocity of the polymer fibers decreases as a function of a distance from device **20**. Hence, the polymer fibers arrive to object **32**, while moving with nearly zero velocity. Due to Coulomb forces present between the charged polymer fibers and the grounded object, the polymer fibers finally sediment on object **32**.

It would be appreciated that the absence of electric field lines closing on object **32** ensures an enhanced coating process, in which the polymer fibers are able to penetrate even into relatively narrow openings. In addition the absence of counteracting volume charge near object **32**, allows a very thin coating the thickness of which is typically of several micrometers.

Depending on the use of the nonwoven material formed by device **20**, it may be required to enhance the strength and/or elasticity of the final product. This is especially important in medical applications, such as

wound dressings, where a combination of high elasticity, strength, small thickness, porosity, and low basis weight are required.

According to a preferred embodiment of the present invention the strength of the nonwoven material may be significantly enhanced, by employing an additional electric field having at least one rotating element, as described hereinbelow.

Referring to Figure 3, device **20** further includes a mechanism **52** for intertwining at least a portion of the polymer fibers, so as to provide at least one polymer fiber bundle moving in a direction system **28**. Mechanism **52** may include any mechanical and/or electronic components which are capable for intertwining the polymer fibers "on the fly", as is further detailed hereinunder, with reference to Figures 4-5.

Thus, Figure 4 illustrates one embodiment of the present invention in which mechanism **52** includes a second system of electrodes being laterally displaced from dispenser **22** and preferably at a second potential relative to dispenser **22**. According to a preferred embodiment of the present invention the second system of electrodes may be constructed in any way known in the art for providing an electric field rotating around longitudinal axis **26**.

For example, as shown in Figure 4, the second system of electrodes may include two or more stationary electrodes **62**, connected to at least one power source **64**, so that the potential difference between electrodes **62** and system **28** (and between electrodes **62** and dispenser **22**) varies in time. Power sources **64**, being electronically communicating with each other so as to synchronize a relative phase between electrodes **62**. Hence, each of stationary electrodes **62** generates a time-dependent electric field having a constant direction. The electronic communication between power sources **64** ensures that the sum of all (time-dependent) field vectors is rotating around longitudinal axis **26**.

Reference is now made to Figure 5, in which mechanism **52** is manufactured as at least one rotating electrode **72**, operable to rotate around longitudinal axis **26**. Rotating electrode **72**, being at a second potential relative to dispenser **22**, generates an electric field, the direction of which follows the motion of rotating electrode **72**, hence an electric field having at least one rotating component is generated.

According to the presently preferred embodiment of the invention, in operation mode of device **20**, the liquefied polymer is dispensed by dispenser **22**, and then, subjected to the electric field, moves inside cavity **24**. The electric field has at least one rotating component around longitudinal axis **26** (generated by the potential difference between mechanism **52** and system **28**) and a stationary electric field (generated by the potential difference between dispenser **22** and system **28**). Hence, in addition to the movement in the direction of system **28**, the jets of liquefied polymer, under the effect of the rotating component of the electric field twist around longitudinal axis **26**. The rotation frequency may be controlled by a suitable choice of configuration for the system of electrodes, as well as on the value of the potential differences employed.

At a given time, the effect of the rotating component of the electric field on the jets neighboring mechanism **52** is larger than the effect on the jets which are located far from mechanism **52**. Hence, the trajectories of the fibers start crossing one another, resulting in physical contacts and entanglement between fibers prior to precipitation.

Thus, device **20** generates higher-order formations of fiber bundles from the elementary fibers in the spray jet. The structure of the formed fiber bundles is inhomogeneous and depends on the distance of the fiber bundle from mechanism **52**. Specifically, the extent of fiber twisting and interweaving, and the amount of fibers in the bundle, is an increasing function of the distance from mechanism **52**. During the motion of the

bundles in cavity **24**, they may also intertwine with one another, forming yet thicker bundles.

The bundles, while formed, move in cavity **24**, directed to system of electrodes **28**, and continue, due to the forces provided by mechanism **30**, out of cavity **24** forming the nonwoven material onto object **32**. The formed material has three-dimensional reticular structure, characterized by a large number of sliding contacts between fibers. Such contacts significantly increase the strength of the material, due to friction forces between fibers. The ability of fibers for mutual displacement increases the elasticity of the nonwoven material under loading.

Device **20** may provide enhanced coating onto numerous kinds of objects, for medical as well as for industrial purposes. According to a preferred embodiment of the present invention object **32** may be, for example, a portion of a body of an organism, such as but not limited to, a skin an artery and a vein. Thus the present invention can be used to provide a nonwoven coat onto both internal and external organs. Alternatively, object **32** may be a rotating mandrel having an intricate-profile structure.

In medical applications, the present invention can be used to provide wound dressing without the need to stretch the dressing, prior to or during application.

Thus, according to another aspect of the invention there is provided a method of wound dressing by electrospinning. The method comprises the following steps which may be executed, for example, using device **20**. Hence, in a first step a liquefied polymer is dispensed within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of polymer fibers moving along the longitudinal axis. In a second step, the polymer fibers are being relocated out of the cavity, in a direction of an object so as to generate a wound dressing thereupon.

According to a preferred embodiment of the present invention, the method may further comprise the step of intertwining at least a portion of the polymer fibers, so as to provide at least one polymer fiber bundle moving in the direction of the object.

The liquefied polymer may be chosen, as further detailed hereinunder, so as to allow maximal flexibility of the dressing. Moreover, since the process wound dressing (as employed, *e.g.*, by device **20**) requires no hand contact with the nonwoven material during application, the present invention successfully maintains the sterility of the dressing during the application process.

Some skin defects, such as burns and deep cuts, demand continues or frequent drug treatment, which treatment, according to prior art methods of wound dressings, can be employed only on open wound. According to a preferred embodiment of the present invention the method may further comprise the step of incorporating at least one drug within the liquefied polymer, for delivery of the drug into the wound during or after generating the wound dressing. Hence the present invention provides solution to the problem of continues drug delivery, without the need to stripe off the wound dressing.

The process described hereinabove, ensures efficient manufacturing of nonwoven materials, which enjoy several mechanical and physical characteristics.

Hence, according to a preferred embodiment of the present invention, there is provided a nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry. The wound dressing having various physical, mechanical and pharmacological, properties, which may be any combination of the following characteristics: (a) having a predetermined porosity; (b) flexible in accordance with a motion of the individual; (c) removable when placed under a sufficient amount of liquid; and (d) having at least one drug

incorporated therein, for delivery of the drug into a body vasculature during or after application of the wound dressing.

It would be appreciated that when a skin defect is characterized by a large area of skin loss (such as in the case of a burn), the wound dressing may serve, at least temporarily, as an artificial skin, preventing exposure to infectious agents.

Besides being of utmost importance in numerous medical applications, device **20** and the method described above are useful in many other industrial applications. For example, the present invention can be employed for identification of individuals via fingerprints.

Thus, according to yet another aspect of the present invention there is provided a method of recording a fingerprint of a finger of an individual. The method comprising the steps of coating the finger by a nonwoven material and removing the nonwoven material from the finger so as to produce data information representative of the fingerprint of the finger.

As can be understood, the step of coating the finger is similar to the coating process detailed hereinabove, and it may be executed, for example, using device **20**. Hence, once the coat is carefully removed from the finger a mirror image of the fingerprint is obtained on the inner surface of the coat. This mirror image may be processed in any method known in the art for the purpose of identifying the individual, constructing an appropriate data base or for any other purpose. In one example, the polymer fibers are manufactured with predetermined magnetic properties, so that the coat, once removed from the finger, may be used as an electronic identification device. Such a device may be used, *e.g.*, as an "electronic key", which biometrically identifies a user by his fingerprint.

By a proper choice of the ingredients of the liquefied polymer, the present invention can also be used for adhering two objects. This can be done by more than one way. For example, if the objects to be joint are characterized by sufficient contact surface, the adhering is done by coating

(employing the above described method) at least one contact surface and attaching the objects to one another. In this case the liquefied polymer is preferably selected to have dominant adhesive properties.

On the other hand, the two objects may be, for example, two blood vessels having open ends which need to be connected to one another during a surgery operation. In this case, the liquefied polymer is preferably selected to have dominant biological properties, such as, but not limited to, biocompatibility and/or biodegradability.

According to a preferred embodiment of the present invention the method of connecting the vessels comprises the steps of attaching the two open ends and, via electrospinning (using the method described above) providing a coat onto at least a portion of the two vessels so as to adhere the two open ends.

According to a preferred embodiment of the present invention, the liquefied polymer loaded into dispenser **22** may be, for example polyurethane, polyester, polyolefin, polymethylmethacrylate, polyvinyl aromatic, polyvinyl ester, polyamide, polyimide, polyether, polycarbonate, polyacrilonitrile, polyvinyl pyrrolidone, polyethylene oxide, poly (L-lactic acid), poly (lactide-CD-glycoside), polycaprolactone, polyphosphate ester, poly (glycolic acid), poly (DL-lactic acid), and some copolymers. Biolmolecules such as DNA, silk, chitozan and cellulose may also be used in mix with synthetic polymers. Improved charging of the polymer may also be required. Improved charging is effected according to the present invention by mixing the liquefied polymer with a charge control agent (e.g., a dipolar additive) to form, for example, a polymer-dipolar additive complex which apparently better interacts with ionized air molecules formed under the influence of the electric field. The charge control agent is typically added in the grams equivalent per liter range, say, in the range of from about 0.001 N to about 0.1 N, depending on the respective molecular weights of the polymer and the charge control agent used.

U.S. Pat. Nos. 5,726,107; 5,554,722; and 5,558,809 teach the use of charge control agents in combination with polycondensation processes in the production of electret fibers, which are fibers characterized in a permanent electric charge, using melt spinning and other processes devoid of the use of a precipitation electrode. A charge control agent is added in such a way that it is incorporated into the melted or partially melted fibers and remains incorporated therein to provide the fibers with electrostatic charge which is not dissipating for prolonged time periods, say weeks or months. In a preferred embodiment of the present invention, the charge control agent transiently binds to the outer surface of the fibers and therefore the charge dissipates shortly thereafter. This is because polycondensation is not exercised at all such that the chemical interaction between the agent and the polymer is absent, and further due to the low concentration of charge control agent employed. The resulting material is therefore, if so desired, substantially charge free.

Suitable charge control agents include, but are not limited to, mono- and poly-cyclic radicals that can bind to the polymer molecule via, for example, -C=C-, =C-SH- or -CO-NH- groups, including biscationic amides, phenol and uryl sulfide derivatives, metal complex compounds, triphenylmethanes, dimethylmidazole and ethoxytrimethylsians.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives,

modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims. All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention.

WHAT IS CLAIMED IS:

1. An electrospinning device for generating a coat from a liquefied polymer, the device comprising:

(a) a dispenser for dispensing the liquefied polymer;

(b) a cavity having a longitudinal axis, comprising a first system of electrodes; said dispenser and said first system of electrodes being constructed and design such that the liquefied polymer is dispensed from said dispenser and forms a plurality of polymer fibers moving along said longitudinal axis; and

(c) a mechanism for relocating said polymer fibers out of said cavity, in a direction of an object, so as to generate a coat on said object.

2. The electrospinning device of claim 1, wherein said mechanism comprises at least one blower, positioned adjacent to said dispenser, and generating an airflow substantially directed along said longitudinal axis.

3. The electrospinning device of claim 1, wherein said object is a portion of a body of an organism.

4. The electrospinning device of claim 1, wherein said object is a skin of an organism.

5. The electrospinning device of claim 1, wherein said object is a wounded skin of an organism.

6. The electrospinning device of claim 3, wherein said portion is selected from the group consisting of an internal portion and an external portion of the organism.

7. The electrospinning device of claim 1, wherein said object is selected from the group consisting of an artery and a vein.

8. The electrospinning device of claim 1, wherein said object is a rotating mandrel.

9. The electrospinning device of claim 1, wherein said dispenser comprises a mechanism for forming a jet of the liquefied polymer.

10. The electrospinning device of claim 9, wherein said mechanism for forming a jet of the liquefied polymer includes a dispensing electrode.

11. The electrospinning device of claim 1, further comprising a first reservoir for holding the liquefied polymer.

12. The electrospinning device of claim 1, further comprising a second reservoir for holding a pharmaceutical agent to be mixed with the liquefied polymer.

13. The electrospinning device of claim 1, wherein said first system of electrodes comprises a circular electrode being at a first potential relative to said dispenser, and spaced apart from said dispenser, along said longitudinal axis.

14. The electrospinning device of claim 1, further comprising a mechanism for intertwining at least a portion of said plurality of polymer fibers, so as to provide at least one polymer fiber bundle moving along said longitudinal axis.

15. The electrospinning device of claim 14, wherein said mechanism for intertwining at least a portion of said plurality of polymer fibers comprises a second system of electrodes, being laterally displaced from said dispenser, being at a second potential relative to said dispenser and capable of providing an electric field having at least one rotating component about said longitudinal axis.

16. The electrospinning device of claim 15, wherein said second system of electrodes includes at least one rotating electrode, operable to rotate about said longitudinal axis.

17. The electrospinning device of claim 2, wherein said cavity is designed such that a velocity of said airflow increases as a function of a distance from said dispenser along said longitudinal axis.

18. The electrospinning device of claim 1, wherein said cavity is characterized by a gradually decreases cross-sectional area as a function of a distance from said dispenser along said longitudinal axis.

19. The electrospinning device of claim 1, wherein said cavity comprises a perforated plate positioned at a first terminal of said cavity.

20. The electrospinning device of claim 1, wherein said cavity is opened at a second terminal of said cavity.

21. The electrospinning device of claim 1, wherein the liquefied polymer is biocompatible.

22. The electrospinning device of claim 1, wherein the liquefied polymer is selected from the group consisting of a biodegradable liquefied polymer and a biostable liquefied polymer.

23. The electrospinning device of claim 1, wherein the liquefied polymer is characterized by predetermined magnetic properties.

24. A method of generating a coat from a liquefied polymer, the method comprising dispensing the liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of polymer fibers moving along said longitudinal axis, and relocating said polymer fibers out of said cavity, in a direction of an object so as to generate a coat onto said object.

25. The method of claim 24, wherein said relocating is done by airflow.

26. The method of claim 24, wherein said object is a portion of a body of an organism.

27. The method of claim 24, wherein said object is a skin of an organism.

28. The method of claim 24, wherein said object is a wounded skin of an organism.

29. The method of claim 26, wherein said portion is selected from the group consisting of an internal portion and an external portion of the organism.

30. The method of claim 24, wherein said object is a blood vessel.

31. The method of claim 29, wherein said object is selected from the group consisting of an artery and a vein.

32. The method of claim 24, wherein said object is a rotating mandrel.

33. The method of claim 24, wherein said dispensing is done by a dispenser.

34. The method of claim 33, wherein said dispenser comprises a mechanism for forming a jet of the liquefied polymer.

35. The method of claim 34, wherein said mechanism for forming a jet of the liquefied polymer includes a dispensing electrode.

36. The method of claim 35, wherein said first electric field is generated by said dispensing electrode and by a first system of electrodes.

37. The method of claim 36, wherein said first system of electrodes comprises a circular electrode being at a first potential relative to said dispenser, and spaced apart from said dispenser, along said longitudinal axis.

38. The method of claim 24, further comprising intertwining at least a portion of said plurality of polymer fibers, so as to provide at least one polymer fiber bundle moving along said longitudinal axis.

39. The method of claim 38, wherein said intertwining is done by a second system of electrodes, being laterally displaced from said dispenser, being at a second potential relative to said dispenser and capable of providing a second electric field having at least one rotating component about said longitudinal axis.

40. The method of claim 39, wherein said second system of electrodes includes at least one rotating electrode, operable to rotate about said longitudinal axis.

41. The method of claim 25, wherein said cavity is designed such that a velocity of said airflow increases as a function of a distance from said dispenser along said longitudinal axis.

42. The method of claim 24, wherein said cavity is characterized by a gradually decreases cross-sectional area along a direction of motion of said polymer fibers.

43. The method of claim 24, wherein said cavity comprises a perforated plate positioned at a first terminal of said cavity.

44. The method of claim 24, wherein said cavity is opened at a second terminal of said cavity.

45. The method of claim 26, further comprising incorporating at least one drug within said liquefied polymer, for delivery of said at least one drug into a vasculature of said organism, during or after generating the coat.

46. The method of claim 30, further comprising incorporating at least one drug within said liquefied polymer, for delivery of said at least one drug into said vessel during or after generating the coat.

47. The method of claim 24, wherein the liquefied polymer is biocompatible.

48. The method of claim 24, wherein the liquefied polymer is selected from the group consisting of a biodegradable liquefied polymer and a biostable liquefied polymer.

49. The method of claim 24, wherein the liquefied polymer is characterized by predetermined magnetic properties.

50. A nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing having at least one characteristic selected from the group consisting of:

(a) having a predetermined porosity;
(b) flexible in accordance with a motion of said individual;
(c) removable when placed under a sufficient amount of liquid; and
(d) having at least one drug incorporated therein, for delivery of said at least one drug into said body vasculature during or after application of the wound dressing.

51. The nonwoven sterile wound dressing of claim 50, which is an artificial skin.

52. The nonwoven sterile wound dressing of claim 50, wherein the polymer fibers are biocompatible.

53. The nonwoven sterile wound dressing of claim 50, wherein the polymer fibers are selected from the group consisting of biodegradable the polymer fibers and biostable the polymer fibers.

54. A nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing having at least two characteristics selected from the group consisting of:

(a) having a predetermined porosity;

(b) flexible in accordance with a motion of said individual;

(c) removable when placed under a sufficient amount of liquid; and

(d) having at least one drug incorporated therein, for delivery of said at least one drug into said body vasculature during or after application of the wound dressing.

55. The nonwoven sterile wound dressing of claim 54, which is an artificial skin.

56. The nonwoven sterile wound dressing of claim 54, wherein the polymer fibers are biocompatible.

57. The nonwoven sterile wound dressing of claim 54, wherein the polymer fibers are selected from the group consisting of biodegradable the polymer fibers and biostable the polymer fibers.

58. A nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing having at least three characteristics selected from the group consisting of:

(a) having a predetermined porosity;
(b) flexible in accordance with a motion of said individual;
(c) removable when placed under a sufficient amount of liquid; and
(d) having at least one drug incorporated therein, for delivery of said at least one drug into said body vasculature during or after application of the wound dressing.

59. The nonwoven sterile wound dressing of claim 58, which is an artificial skin.

60. The nonwoven sterile wound dressing of claim 58, wherein the polymer fibers are biocompatible.

61. The nonwoven sterile wound dressing of claim 58, wherein the polymer fibers are selected from the group consisting of biodegradable the polymer fibers and biostable the polymer fibers.

62. A nonwoven sterile wound dressing comprising at least one layer of polymer fibers shaped in accordance with an individual wound and body geometry, the nonwoven wound dressing:

(a) having a predetermined porosity;
(b) flexible in accordance with a motion of said individual;
(c) removable when placed under a sufficient amount of liquid; and

(d) having at least one drug incorporated therein, for delivery of said at least one drug into said body vasculature during or after application of the wound dressing.

63. The nonwoven sterile wound dressing of claim 62, which is an artificial skin.

64. The nonwoven sterile wound dressing of claim 62, wherein the polymer fibers are biocompatible.

65. The nonwoven sterile wound dressing of claim 62, wherein the polymer fibers are selected from the group consisting of biodegradable the polymer fibers and biostable the polymer fibers.

66. A method of connecting two vessels having open ends, the method comprising, attaching the two open ends of the two vessels and, via electrospinning, providing a coat onto at least a portion of the two vessels so as to adhere the two open ends.

67. The method of claim 66, wherein said providing a coat comprises dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of polymer fibers moving along said longitudinal axis, and relocating said polymer fibers out of said cavity, in a direction of said at least a portion of the two vessels.

68. The method of claim 67, wherein said relocating is done by airflow.

69. The method of claim 67, wherein said dispensing is done by a dispenser.

70. The method of claim 69, wherein said dispenser comprises a mechanism for forming a jet of said liquefied polymer.

71. The method of claim 70, wherein said mechanism for forming a jet of said liquefied polymer includes a dispensing electrode.

72. The method of claim 71, wherein said first electric field is generated by said dispensing electrode and by a first system of electrodes.

73. The method of claim 72, wherein said first system of electrodes comprises a circular electrode being at a first potential relative to said dispenser, and spaced apart from said dispenser, along said longitudinal axis.

74. The method of claim 67, further comprising intertwining at least a portion of said plurality of polymer fibers, so as to provide at least one polymer fiber bundle moving along said longitudinal axis.

75. The method of claim 74, wherein said intertwining is done by a second system of electrodes, being laterally displaced from said dispenser, being at a second potential relative to said dispenser and capable of providing a second electric field having at least one rotating component about said longitudinal axis.

76. The method of claim 75, wherein said second system of electrodes includes at least one rotating electrode, operable to rotate about said longitudinal axis.

77. The method of claim 68, wherein said cavity is designed such that a velocity of said airflow increases as a function of a distance from said dispenser along said longitudinal axis.

78. The method of claim 67, wherein said cavity is characterized by a gradually decreases cross-sectional area along a direction of motion of said polymer fibers.

79. The method of claim 67, wherein said cavity comprises a perforated plate positioned at a first terminal of said cavity.

80. The method of claim 67, wherein said cavity is opened at a second terminal of said cavity.

81. The method of claim 67, further comprising incorporating at least one drug within said liquefied polymer, for delivery of said at least one drug into at least one vessel during or after providing the coat.

82. The method of claim 67, wherein said liquefied polymer is biocompatible.

83. The method of claim 67, wherein said liquefied polymer is selected from the group consisting of a biodegradable liquefied polymer and a biostable liquefied polymer.

84. A method of recording a fingerprint of an individual having a finger, the method comprising:

via electrospinning, coating the finger by a nonwoven material; and

removing said nonwoven material from the finger so as to produce data information representative of the fingerprint of the finger.

85. The method of claim 84, wherein said nonwoven material is made from polymer fibers.

86. The method of claim 85, wherein said coating comprises dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of said polymer fibers moving along said longitudinal axis, and relocating said polymer fibers out of said cavity, in a direction of the finger so as to generate a coat onto the finger.

87. The method of claim 86, wherein said relocating is done by airflow.

88. The method of claim 86, wherein said dispensing is done by a dispenser.

89. The method of claim 88, wherein said dispenser comprises a mechanism for forming a jet of said liquefied polymer.

90. The method of claim 89, wherein said mechanism for forming a jet of said liquefied polymer includes a dispensing electrode.

91. The method of claim 90, wherein said first electric field is generated by said dispensing electrode and by a first system of electrodes.

92. The method of claim 91, wherein said first system of electrodes comprises a circular electrode being at a first potential relative to said dispenser, and spaced apart from said dispenser, along said longitudinal axis.

93. The method of claim 86, further comprising intertwining at least a portion of said plurality of polymer fibers, so as to provide at least one polymer fiber bundle moving along said longitudinal axis.

94. The method of claim 93, wherein said intertwining is done by a second system of electrodes, being laterally displaced from said dispenser, being at a second potential relative to said dispenser and capable of providing a second electric field having at least one rotating component about said longitudinal axis.

95. The method of claim 94, wherein said second system of electrodes includes at least one rotating electrode, operable to rotate about said longitudinal axis.

96. The method of claim 87, wherein said cavity is designed such that a velocity of said airflow increases as a function of a distance from said dispenser along said longitudinal axis.

97. The method of claim 86, wherein said cavity is characterized by a gradually decreases cross-sectional area along a direction of motion of said polymer fibers.

98. The method of claim 86, wherein said cavity comprises a perforated plate positioned at a first terminal of said cavity.

99. The method of claim 86, wherein said cavity is opened at a second terminal of said cavity.

100. The method of claim 86, wherein said liquefied polymer is biocompatible.

101. The method of claim 86, wherein said liquefied polymer is selected from the group consisting of a biodegradable liquefied polymer and a biostable liquefied polymer.

102. The method of claim 1, wherein said liquefied polymer is characterized by predetermined magnetic properties.

103. A method of adhering two objects having contact surfaces, the method comprising:

via electrospinning, coating at least one contact surface by a nonwoven material; and

attaching the contact surfaces together hence adhering the two objects.

104. The method of claim 103, wherein said nonwoven material is made from polymer fibers.

105. The method of claim 104, wherein said coating comprises dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of said polymer fibers moving along said longitudinal axis, and relocating said polymer fibers out of said cavity, in a direction of said at least one contact surface.

106. The method of claim 105, wherein said relocating is done by airflow.

107. The method of claim 105, wherein said dispensing is done by a dispenser.

108. The method of claim 107, wherein said dispenser comprises a mechanism for forming a jet of said liquefied polymer.

109. The method of claim 108, wherein said mechanism for forming a jet of said liquefied polymer includes a dispensing electrode.

110. The method of claim 109, wherein said first electric field is generated by said dispensing electrode and by a first system of electrodes.

111. The method of claim 110, wherein said first system of electrodes comprises a circular electrode being at a first potential relative to said dispenser, and spaced apart from said dispenser, along said longitudinal axis.

112. The method of claim 105, further comprising intertwining at least a portion of said plurality of polymer fibers, so as to provide at least one polymer fiber bundle moving along said longitudinal axis.

113. The method of claim 112, wherein said intertwining is done by a second system of electrodes, being laterally displaced from said dispenser, being at a second potential relative to said dispenser and capable of providing a second electric field having at least one rotating component about said longitudinal axis.

114. The method of claim 113, wherein said second system of electrodes includes at least one rotating electrode, operable to rotate about said longitudinal axis.

115. The method of claim 106, wherein said cavity is designed such that a velocity of said airflow increases as a function of a distance from said dispenser along said longitudinal axis.

116. The method of claim 105, wherein said cavity is characterized by a gradually decreases cross-sectional area along a direction of motion of said polymer fibers.

117. The method of claim 105, wherein said cavity comprises a perforated plate positioned at a first terminal of said cavity.

118. The method of claim 105, wherein said cavity is opened at a second terminal of said cavity.

119. The method of claim 105, wherein said liquefied polymer is biocompatible.

120. The method of claim 105, wherein said liquefied polymer is selected from the group consisting of a biodegradable liquefied polymer and a biostable liquefied polymer.

121. A method of wound dressing by electrospinning, the method comprising dispensing a liquefied polymer within a first electric field present in a cavity having a longitudinal axis, thereby providing a plurality of polymer fibers moving along said longitudinal axis, and relocating said polymer fibers out of said cavity, in a direction of an object so as to generate a wound dressing onto said object.

122. The method of claim 121, wherein said relocating is done by airflow.

123. The method of claim 121, wherein said object is a portion of a body of an organism.

124. The method of claim 121, wherein said object is a skin of an organism.

125. The method of claim 121, wherein said object is a wounded skin of an organism.

126. The method of claim 123, wherein said portion is selected from the group consisting of an internal portion and an external portion of the organism.

127. The method of claim 121, wherein said object is a blood vessel.

128. The method of claim 126, wherein said object is selected from the group consisting of an artery and a vein.

129. The method of claim 121, wherein said object is a rotating mandrel.

130. The method of claim 121, wherein said dispensing is done by a dispenser.

131. The method of claim 130, wherein said dispenser comprises a mechanism for forming a jet of said liquefied polymer.

132. The method of claim 131, wherein said mechanism for forming a jet of said liquefied polymer includes a dispensing electrode.

133. The method of claim 132, wherein said first electric field is generated by said dispensing electrode and by a first system of electrodes.

134. The method of claim 133, wherein said first system of electrodes comprises a circular electrode being at a first potential relative to said dispenser, and spaced apart from said dispenser, along said longitudinal axis.

135. The method of claim 121, further comprising intertwining at least a portion of said plurality of polymer fibers, so as to provide at least one polymer fiber bundle moving along said longitudinal axis.

136. The method of claim 135, wherein said intertwining is done by a second system of electrodes, being laterally displaced from said dispenser, being at a second potential relative to said dispenser and capable of providing a second electric field having at least one rotating component about said longitudinal axis.

137. The method of claim 136, wherein said second system of electrodes includes at least one rotating electrode, operable to rotate about said longitudinal axis.

138. The method of claim 122, wherein said cavity is designed such that a velocity of said airflow increases as a function of a distance from said dispenser along said longitudinal axis.

139. The method of claim 121, wherein said cavity is characterized by a gradually decreases cross-sectional area along a direction of motion of said polymer fibers.

140. The method of claim 121, wherein said cavity comprises a perforated plate positioned at a first terminal of said cavity.

141. The method of claim 121, wherein said cavity is opened at a second terminal of said cavity.

142. The method of claim 123, further comprising incorporating at least one drug within said liquefied polymer, for delivery of said at least one drug into a vasculature of said organism, during or after generating the coat.

143. The method of claim 127, further comprising incorporating at least one drug within said liquefied polymer, for delivery of said at least one drug into said vessel during or after generating the coat.

144. The method of claim 121, wherein said liquefied polymer is biocompatible.

145. The method of claim 121, wherein said liquefied polymer is selected from the group consisting of a biodegradable liquefied polymer and a biostable liquefied polymer.

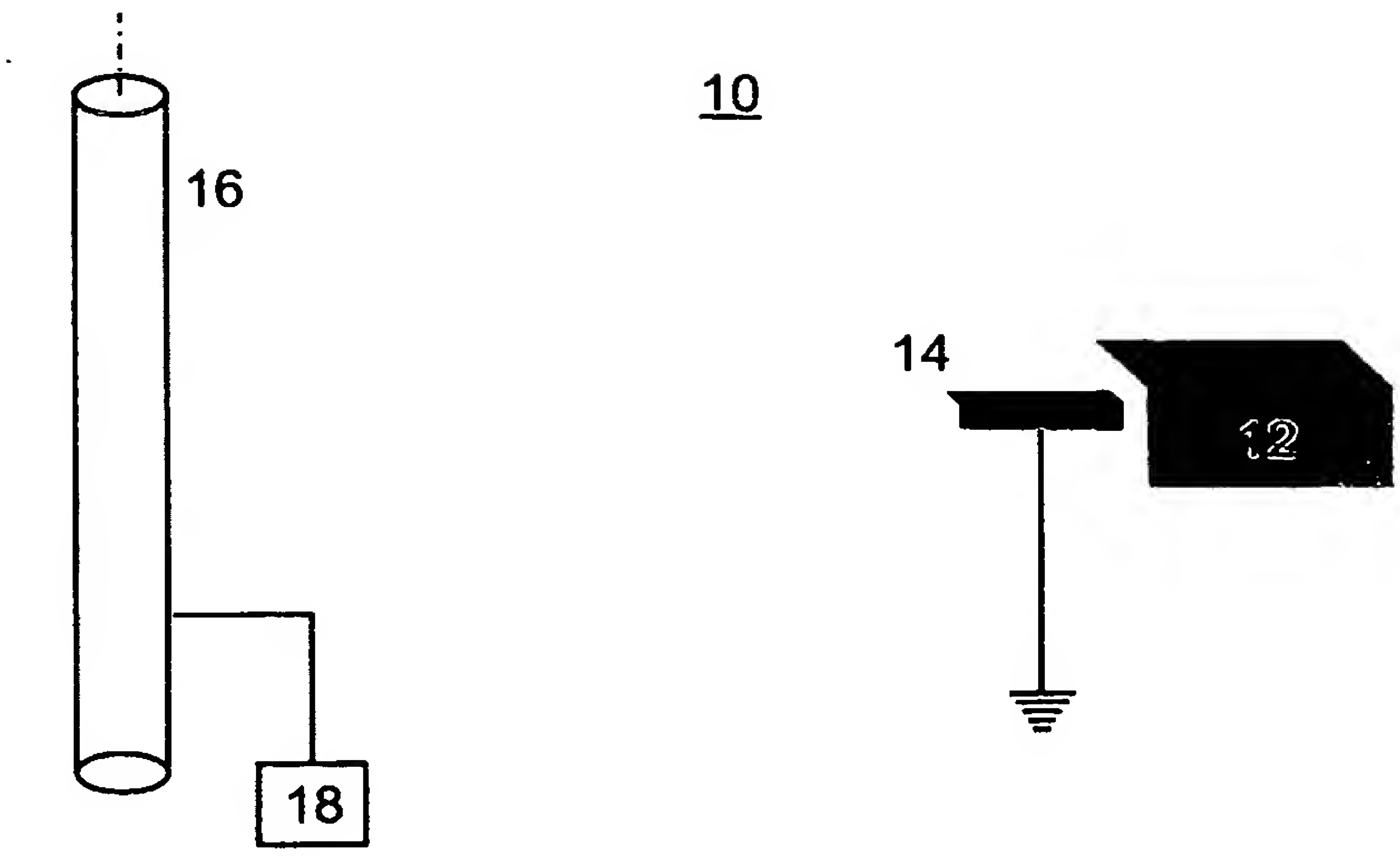

Fig. 1 (Prior Art)

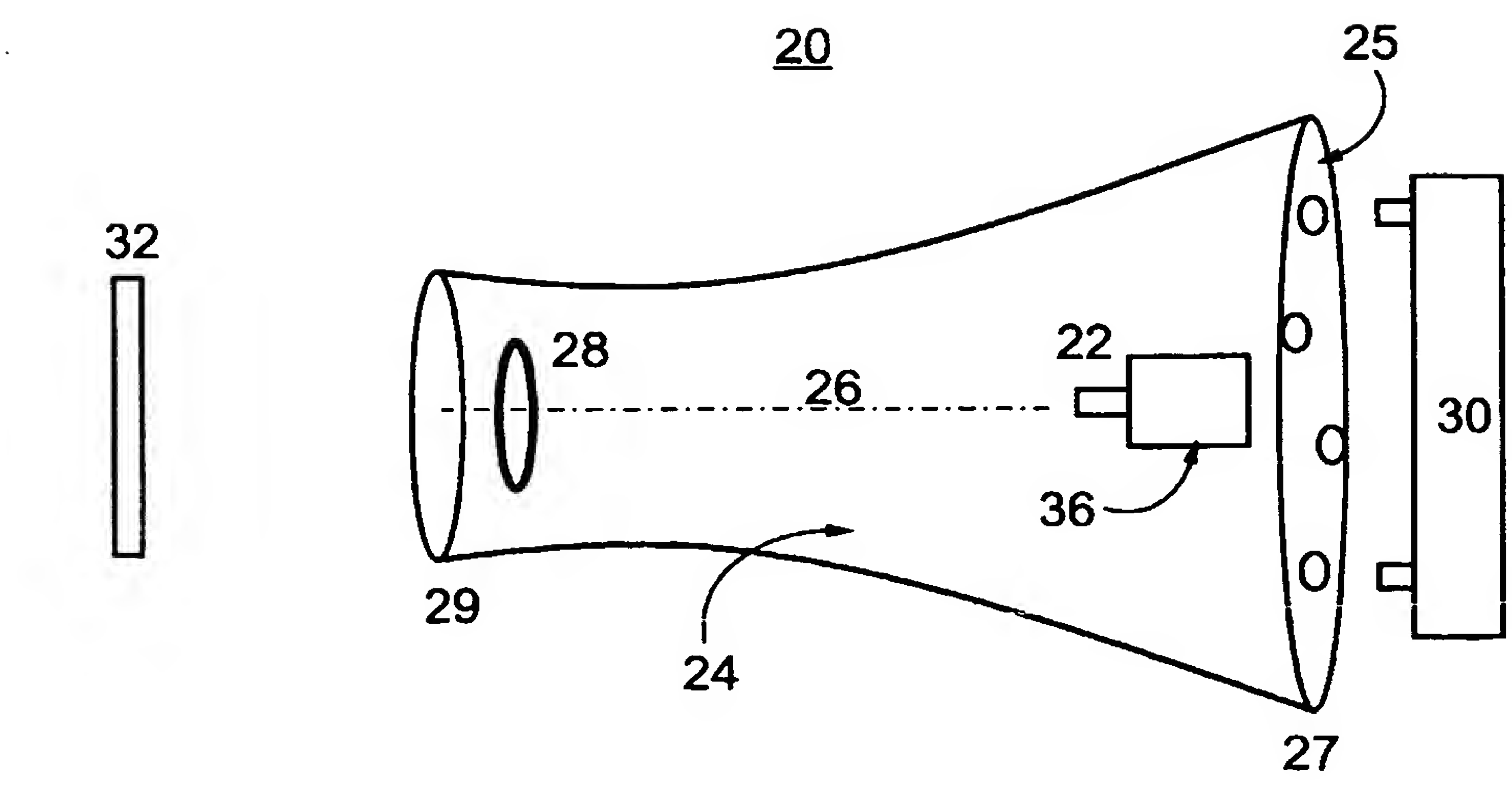

Fig. 2

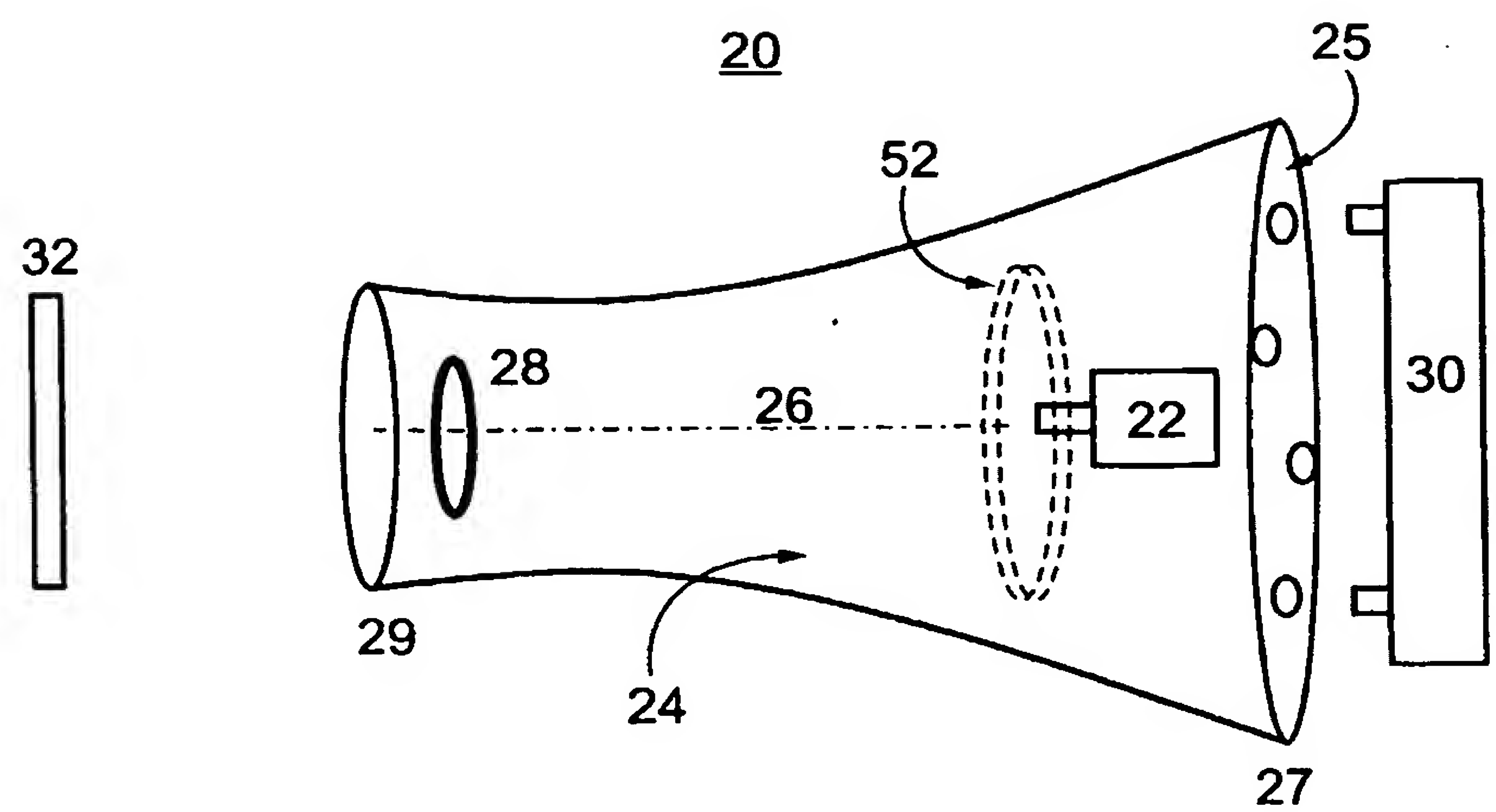

Fig. 3

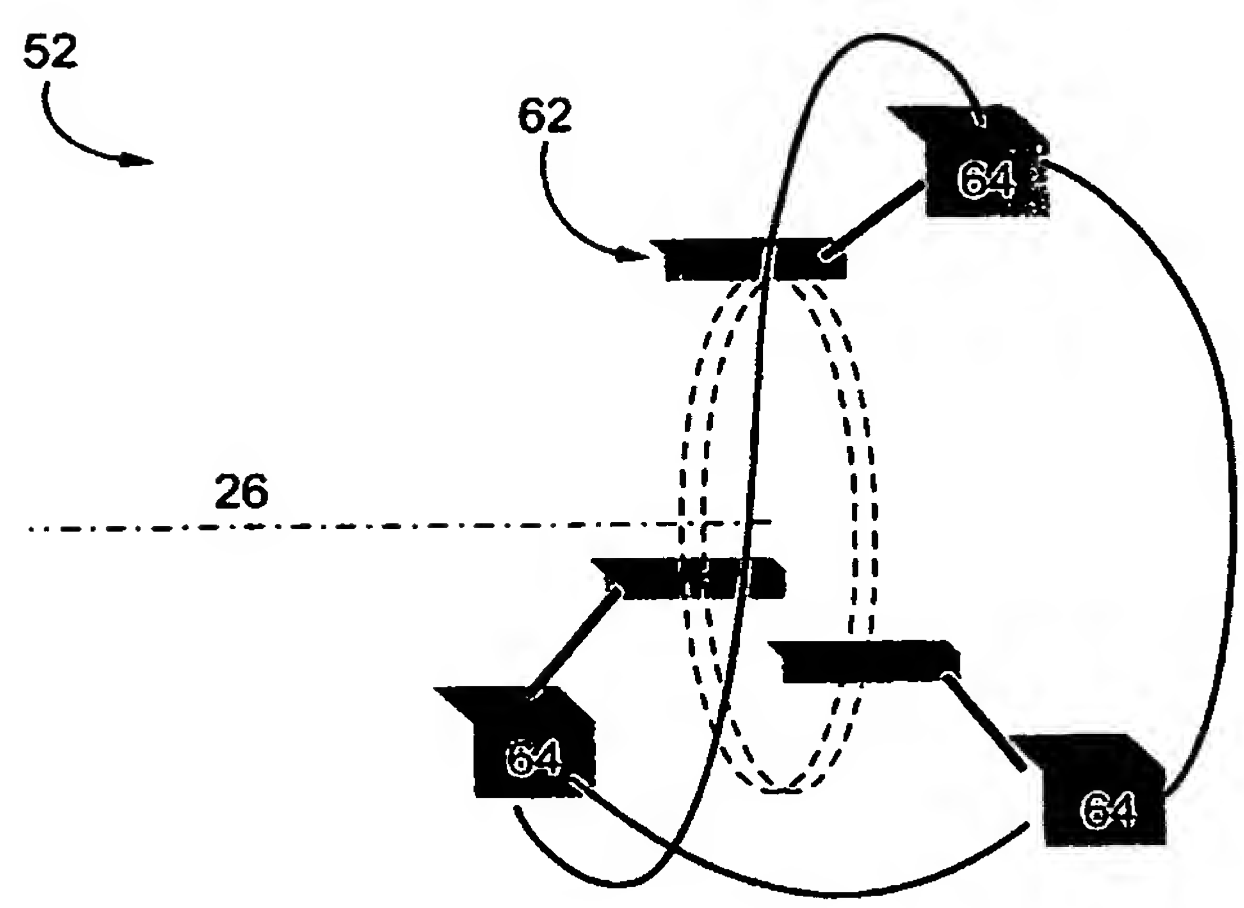

Fig. 4

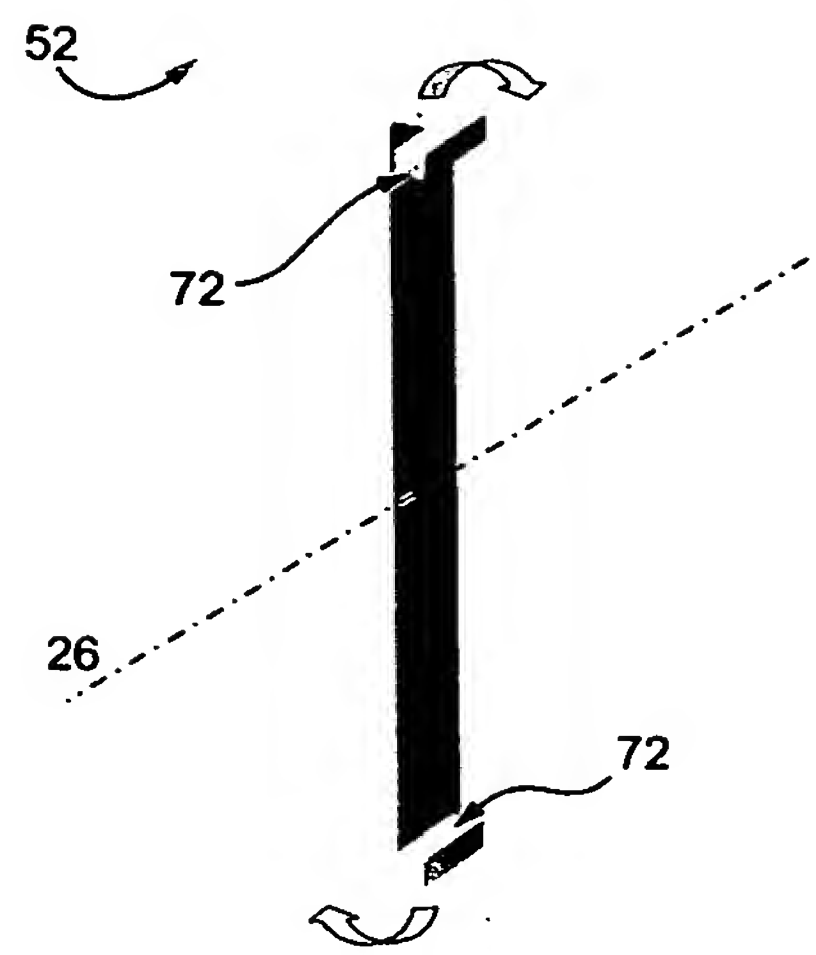

Fig. 5

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(81) Designated States *(national)*: AE, AG, AL, AM, AT (utility model), AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), CZ, DE (utility model), DE, DK (utility model), DK, DM, DZ, EC, EE (utility model), EE, ES, FI (utility model), FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK (utility model), SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

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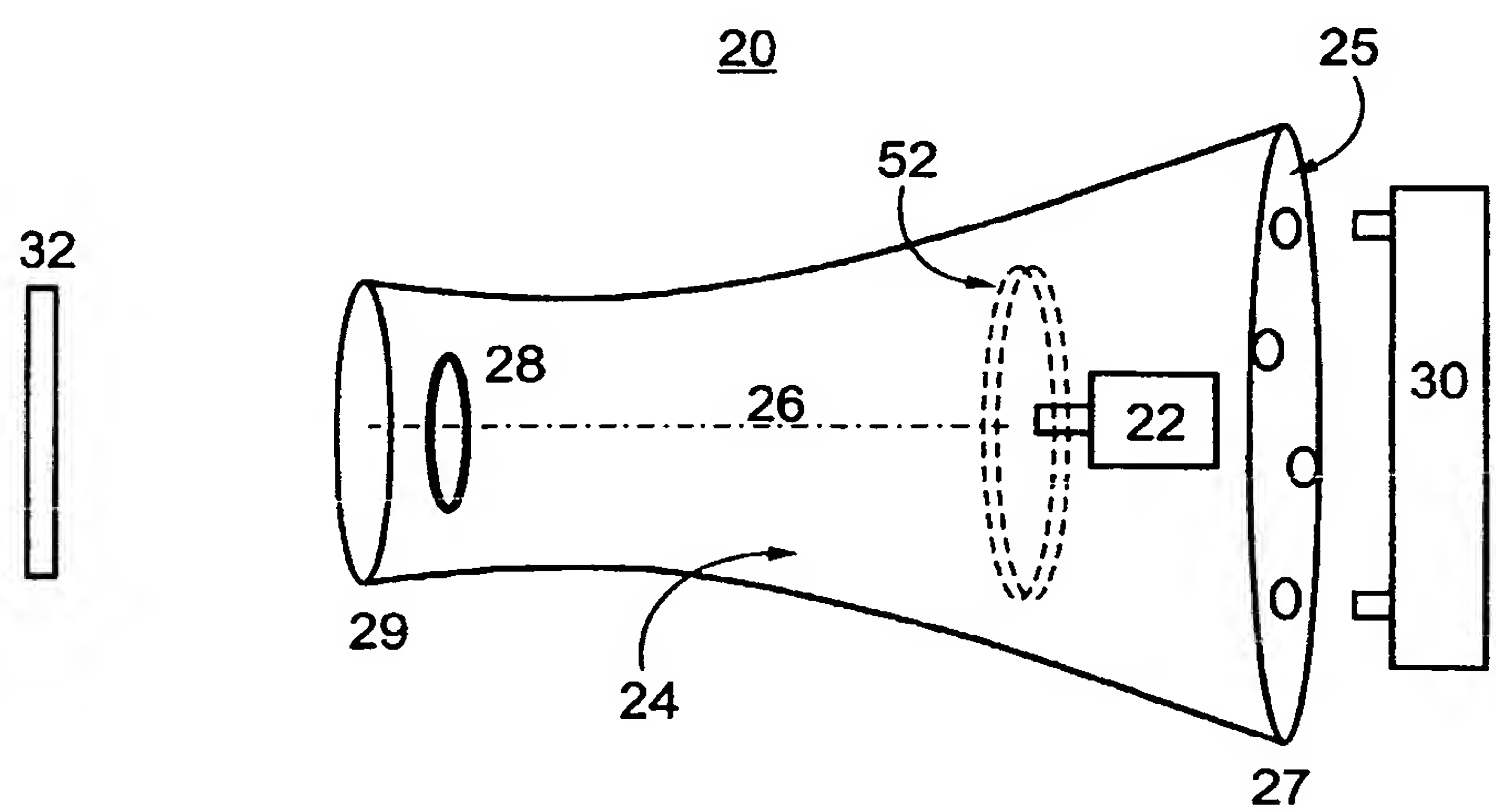
Published:
— *with international search report*

(88) Date of publication of the international search report: 6 February 2003

[Continued on next page]

(54) Title: PORTABLE ELECTROSPINNING DEVICE



(57) Abstract: An electrospinning device for generating a coat from a liquefied polymer, the device comprising: (a) a dispenser for dispensing the liquefied polymer; (b) a cavity having a longitudinal axis, comprising a first system of electrodes; the dispenser and the first system of electrodes being constructed and design such that the liquefied polymer is dispensed from the dispenser and forms a plurality of polymer fibers moving along the longitudinal axis; and (c) a mechanism for relocating the polymer fibers out of the cavity, in a direction of an object, so as to generate a coat on the object.

WO 02/074191 A3

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL02/00220

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : B29B 013/08
US CL : 425/174.8E
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 425/174.8E, 174.8R; 264/10, 484, 441; 427/2.31, 458, 472, 483; 606/45, 58; 118/629; 428/36.4, 292.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 3,860,369 (BRETHAUER et al) 14 January 1975 (14.01.1975), Figure 1, col 3, lines 37-47 and col 6, lines 3-35.	1-14, 17-18, 20-25, 32-38, 41-42, 44, 49, 102 — 26-31, 45-48, 121-135, 138-139, 141, 144-145
X — Y	US 4,345,414 (BORNAT et al) 24 August 1982 (24.08.1982), Figure 1, col 7, lines 23-68, col 8, lines 1-59.	50-61 — 26-31, 45-48, 62-65, 127-128
Y	EP 523960 A1 (UNILEVER) 20 January 1993 (19.01.1993).	26-31, 45-48, 121-135, 138-139, 141, 144-145
Y	US 6,117,425 (MACPHEE et al) 12 September 2000 (12.09.2000), column 7, lines 15-35.	62-65
Y, P	US 6,270,793 B1 (VAN DYKE et al) 07 August 2001 (07.08.2001), column 2, lines 1-21.	62-65

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2002 (25.09.2002)	21 NOV 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Joseph S. Del Sole Telephone No. (703) 308-6295

DEBORAH THOMAS
PARALEGAL SPECIALIST

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL02/00220

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: of Group I, claims 1-65, 102, 121-145

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-65, 102, 121-145, drawn to apparatus and method for electrospinning a liquefied polymer, and the nonwoven product made from the apparatus and method.

Group II, claim(s) 66-83, drawn to a method for connecting two vessels.

Group III, claim(s) 84-101, drawn to a method for recording a fingerprint.

Group IV, claim(s) 103-120, drawn to method for adhering two objects having contact surfaces.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

All of the groups are directed generally to the method, apparatus and product related to a nonwoven material formed by electrospinning, but each group has different special technical features.

Group I has a special technical feature drawn to a nonwoven material electrospun by a dispenser through a cavity with the polymer fibers being relocated out of the cavity and onto the object and having particular porosity, flexibility, removability and drug deliver characteristics.
Group II has a special technical feature drawn to the connection of two open ends of two vessels via electrospinning as its special technical feature.
Group III has a special technical feature drawn to electrospinning a coating on a finger to record a fingerprint.
Group IV has a special technical feature drawn to electrospinning two contact surfaces into attachment together by a nonwoven material.